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HUMAN FACTORS ENGINEERING DESIGN CRITERIA FOR FUTURE SYSTEMS, REPORT NO. 3: DESIGN CRITERIA EVOLVING FROM THE MULTIPLE LAUNCH ROCKET SYSTEM (MLRS) OPERATIONAL TEST III

ARI Field Unit at Fort Hood, Texas
Systems Research Laboratory

January 1985

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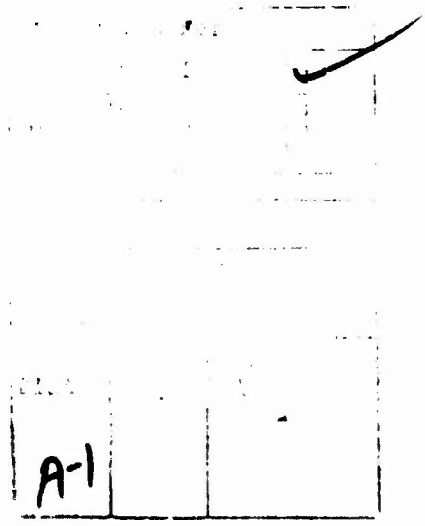

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This document compares human factors engineering related problems identified in the U.S. Army Operational Test and Evaluation Agency MLRS Operational Test III with relevant criteria statements from MIL-HDBK-759A and MIL-STD-1472C. These criteria were reviewed to determine if they provided adequate guidance for making informed design judgments. Areas where existing criteria are inadequate or nonexistent were identified and new complete criteria developed. The new criteria are presented in a format designed to facilitate their use in the design of future similar systems.

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FOREWORD

A major research project of the Army Research Institute (ARI) Field Unit at Fort Hood, TX, is "Evaluating Human Factors Considerations and Concepts in an Operational Environment" (Army Project 2Q263739A793). This project is primarily concerned with evaluating the human factors (man-machine interface) aspects of systems in an operational environment; the purpose is to optimize performance of existing systems and provide design criteria for future similar systems. One of these evaluations was the human factors evaluation of the M270 Self Propelled Launcher Loader (SPLL) and M985 Heavy Expanded Mobility Tactical Truck (HEMTT) in the Multiple Launch Rocket System (MLRS) Operational Test III. This report describes the results of an analysis of data from this OT III which resulted in the identification of important current design criteria in MIL-STD-1472C and MIL-HDBK-759A and the development of new criteria. These criteria provide the design guidance necessary for: (1) resolving current human factors engineering problems with present MLRS vehicles, and (2) preventing the recurrence of such problems in future MLRS or similar systems. The report does not address current design criteria which are adequate and which were properly considered during the RDT&E process, i.e., design criteria relating to system aspects where no man-machine interface problems were found.

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HUMAN FACTORS ENGINEERING DESIGN CRITERIA FOR FUTURE SYSTEMS, REPORT NO. 3: DESIGN CRITERIA EVOLVING FROM THE MULTIPLE LAUNCH ROCKET SYSTEM (MLRS) OPERATIONAL TEST III

EXECUTIVE SUMMARY

Requirement:

The objective of this document is to specify current human factors engineering (HFE) related design criteria that are associated with current HFE problems in the two vehicles comprising the Multiple Launch Rocket System (MLRS): the M270 Self Propelled Launcher Loader (SPLL) and the M985 Heavy Expanded Mobility Tactical Truck (HEMTT) and to stipulate new design criteria, where needed, in order to prevent a recurrence of these problems in future systems similar to the MLRS.

Procedure:

The procedure involved comparing individual HFE design problems identified in the MLRS Operational Test III with relevant criteria statements containing the information for avoiding such problems in the design process. (The MLRS Human Factors Engineering Evaluation in OT III is presented in detail in ARI Research Report 1387, "Human Factors Analysis of the Multiple Launch Rocket System [MLRS] in Operational Test III," December 1984.) The criteria in MIL-STD-1472C and MIL-HDBK-759A were evaluated to determine if they provided adequate guidance for making informed design judgments. Criteria judged as adequate were viewed as critical criteria that should be given greater emphasis in future programs. In comparisons in which the criteria were judged as inadequate or missing, revised or new criteria were proposed.

Findings:

The HFE problems were distributed across 36 different equipment components in the SPLL and 17 in the HEMTT. Current criteria are available for all of them; they were judged to be adequate for the SPLL in 28 cases and inadequate in 8; for the HEMTT current criteria were adequate in 14 cases and inadequate in 3 cases. Thus adequate design guidance is available in current criteria to avoid most of these problems in future MLRS systems. The most frequent problems on both vehicles were concerned with seating, workspace, stowage, and illumination systems. The first three are elements of comfort considerations in the operator stations. It appears that this outcome occurred because the designers did not take into account the long time periods in which the crew members must occupy their crew stations when performing the MLRS mission. Similarly, the many problems with the illumination systems in the two vehicles appear to be due to a failure to appreciate fully the operational conditions under which they are used.

Utilization of Findings:

These findings are intended for use in improving and updating HFE design criteria for MLRS or similar systems. The critical, revised and new criteria presented in this report provide much of the information necessary for correcting the current HFE problems in the MLRS and preventing the recurrence of similar problems in future generation systems. It is intended that the agencies/organizations responsible for MIL-STD-1472C, MIL-HDBK-759A, and specific systems specifications will extract those proposals which are applicable to their particular areas.

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INTRODUCTION

The Fort Hood Field Unit of ARI has an active program of human factors research with new and improved equipment in the system acquisition process. The research is characterized by assessment of systems in an operational environment when these systems are manned by regular FORSCOM troops for the first time. ARI provides support to TCATA, the test boards and OTEA in fulfilling the requirements of the human factors objectives of operational tests conducted by these agencies. This report is the third in a series on developing design criteria for future systems. Earlier reports (Earl, 1984; Crumley & Earl, 1985) presented criteria evolving from analyses of human factors problems which occurred in the M1 tank Operational Test III and the FIST V Operational Test II.

PURPOSE AND OBJECTIVE

One of the primary functions of the ARI human factors research program is to provide human factors engineering (man-machine interface) design criteria for future systems. This is achieved by an analysis of human factors engineering (HFE) problems identified in user tests of similar current systems. Problems identified in current systems, therefore, serve as the basis for establishing critical design criteria for future similar systems - a process that involves: (1) detecting relevant existing design criteria which have been overlooked or ignored, and (2) identifying and developing new criteria for unanticipated problems not covered by current standards.

The objectives of this analysis are limited to: (1) specifying current HFE related design criteria that are associated with HFE deficiencies in the M270 Self Propelled Launcher (SPLL) and the M985 Heavy Expanded Mobility Tactical Truck (HEMTT); and (2) stipulating new design criteria, where needed, in order to prevent a recurrence in future systems of HFE problems reported in: OTEA Report Multiple Launch Rocket System Operational Test III (MLRS OT III) (April 1983). This current ARI report does not address current design criteria which are adequate and which were properly considered during the RDT&E process, i.e., design criteria relating to system aspects where no man-machine interface problems were found are not addressed.

PROCEDURE

The approach involved comparing the individual HFE problems described in the above report with the applicable criteria statements containing the rules for avoiding the problems. The problems were first identified with the related hardware components and arranged accordingly. The criteria reference sources used in the search were the current issues of MIL-STD-1472 and MIL-HDBK-759, namely, MIL-STD-472C (1981) and MIL-HDBK-759A (1981). During the period of MLRS development in the 1970's, however, it is likely that prior editions, MIL-STD-1472B (1974) and MIL-HDBK-759 (1975), were the versions available for contract application and guidance.

The latest editions were used in this analysis because the main purpose was to produce information to update and revise current standards. Both references were examined to identify those criteria that are pertinent for each problem. Criteria that were judged to be relevant to some degree were included in the selections. The selected criteria were then evaluated to determine whether or not they provided unequivocal and specific guidance for making informed design judgements. In cases where the criteria were judged as adequate in providing sufficient guidance, these were defined as critical criteria that should be given greater emphasis in future programs.

In cases where the existing criteria were judged as relevant but providing inadequate guidance, the comparisons revealed the need for revision to include guidance covering the HFE considerations involved in the design problem. Revised design criteria were then formulated for these cases.

RESULTS

Design criteria data are presented in tables made up of three columns. The first column presents HFE problems described in succinct statements indicating the identity of the hardware components involved and the specific design features causing the problems. In the second column, adjacent to the statements of the HFE problems, are presented relevant current criteria. Each design criterion is presented in a short statement and paraphrased where necessary to include only the parts relevant to the problem. Each criterion statement ends with a number in parenthesis. This number refers to a specific paragraph in the reference sources. Numbers beginning with the letter "S" indicate MIL-STD-1472C and the specific paragraph therein. Numbers beginning with the letter "H" indicate MIL-HDBK-759A and its paragraph number.

The third column presents the proposed new or revised criteria. In cases where the relevant criteria were judged as adequate, no new criteria are presented and the statement "No change" is entered in the column. In other cases where the relevant criteria were judged as inadequate, new or revised criteria are included.

The results for the SPLL and HEMTT are presented in Table 1 and Table 2, respectively.

Table 1

Comparisons of Significant HFE Design Problems in the M270 Self Propelled Launcher Loader (SPLL) during MLRS OT III with Current and Proposed Design Criteria

MLRS OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
Section A. Section Chief's Station		
1. Seat		
1.1. The seat is uncomfortable. It does not provide comfortable support for long periods of continuous occupation required by the mission.	The commander should be provided a seat which is comfortable and can accommodate the full range of suitably clothed Army personnel (5th through 95th percentile) H 7.5.-9.2.1. Seating for vehicle operators should follow the dimensions and clearances recommended in Figures 50 and 51 and H7.5.9.2.1.	Add: The seat should adjust to provide optimum interface with controls, displays and optical equipment.
1.2. The fold-down backrest which is used as a platform when standing in the roof hatch is not designed to stand on; it is not equipped with a platform surface.	The tank commander's seat should be capable of being folded out of the way to allow operation in a standing position. A platform, big enough to accomodate 95th percentile Arctic boots, should be provided (H 7.5.9.2.5).	Crew stations equipped with roof hatches to be used in the standing position should be provided with standing platforms big enough to accomodate 95th percentile Arctic boots.
2. Heater Exhaust Port		
2.1. The exhaust port is located close behind the section chief's door. Diesel fuel exhaust smoke enters the cab and pollutes the crew's air supply whenever the door is opened while the heater is running.	The design of exhaust systems must keep fumes from entering crew and other personnel compartments (H 7.4.7.1). Careful consideration should be given in designing vehicle fighting compartments to provide sufficient ventila-	No change.

Table 1 (continued)

MLRS OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
	tion to maintain noxious exhaust products below an irritating and nauseating level, and the direction and dispersion of these products should minimize exhaust concentrations (H 3.7.7.-3). Carbon monoxide in personnel areas shall be reduced to the lowest level feasible (S 5.13.7.4.2).	
3. Workspace		
3.1. Legroom and bodyroom were rated as inadequate for working and living in for the long time periods the crewman must occupy their stations.	Workspace and sizing shall insure accomodation, compatibility, operability and maintainability by at least 90 percent of the user population (S 5.6.1). Anthropometric data for the design and sizing of workspaces are presented in Table XIX (S 5.7.4). Workspace dimensions should follow the data presented in Table 2-15 (H 2.12).	No change.
4. Sound insulation		
4.1 Noise produced by the engine, tracks and cab air pressure fan is intense enough to detract from the effectivness of many section chiefs.	Personnel shall be provided an acoustical environment which will not cause personnel injury, interfere with voice or any other communications, cause fatigue, or in any other way degrade overall system effectiveness (S 5.8.3.1 and H 3.6.1). The noise levels within crew compartments should not exceed the limits described in the current edition of MIL-STD-1474 (H 7.5.6.4).	No change.

Table 1 (continued)

MLRS OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
5. Section chief's door		
5.1. The relatively heavy armored door is difficult to open because the door handle sticks in the closed position and is difficult to unlatch.	The operator should be able to latch and lock the door easily, in one continuous motion with one hand, from within the vehicle (H 7.5.1.1.3).	No change.
6. M16 rifle rack		
6.1. The location of the muzzle clamp is poor; it is difficult to remove and replace the rifle in the rack. This is a high use item which causes much annoyance.	Access openings provided for handling interior items shall be sized to permit the required operations (S 5.9.9.4.1). Access should be provided (on both sides of equipment if feasible) with sufficient hand room for removal or replacement of equipment (H 7.6.4.-3.c).	Rifle racks in crew stations should be mounted in locations that provide free, unrestricted access for easy removal/replacement of the weapons. Rifle racks are high use items that must be mounted in such a way as to facilitate quick and easy weapon removal/replacement.
7. Ballistic window		
7.1. The ballistic window is difficult to open and close and the curtain is difficult to operate.	The design of military equipment shall reflect human engineering factors that affect human performance including design features to assure rapidity, safety, and ease of operation in normal and adverse environments (S 4.4.-m).	Add: To include opening and c losing of doors, hatch covers and windows
8. Section chief's hatch		
8.1. The hatch is difficult to open and close.	The operator should be able to latch and lock the hatch easily, in one continuous motion with one hand, from within the vehicle (H 7.5.1.1.3).	No change.

Table 1 (continued)

MLRS OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
	Overhead hatches should require no more than 220 Newtons of force for opening/closing, under any condition of vehicle tilt and should be operable by a suitably clothed and equipped user with 5th percentile arm and hand strength (H 7.5.1.2.1).	
9. Suspension lockout display		
9.1. Section chiefs cannot see the suspension lockout display from their station and monitor the mode settings which is critical for safe firing of the self propelled rocket launcher.	When two operators must use the same display (e.g., in monitoring system status), and it has high priority, duplicate sets should be provided whenever there is adequate space Otherwise, displays should be centered between the operators (H 1.3.6.2.2.a). The operator assigned to control and monitor a particular function shall have physical and visual access to all displays necessary to adequately perform assigned tasks (S 4.7).	No change.
Section B. Gunner's Station		
1. Gunner's seat		
1.1. Gunners rate their seat as very uncomfortable and lacking comfortable seatpan and a hard back that causes soreness.	The tank gunner is usually less mobile than the other crew members and presents special problems for the designer. They may be confined to their seats for long periods of time and will require special venilation and seating comfort considerations(H 7.5.10.1).	Seats should include a comfortable seat pan and an adjustable backrest. The seat should provide optimum interface with controls, displays and optical equipment.

Table 1 (continued)

MLRS OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
2. Workspace		
2.1. Gunners rated the headroom, legroom and bodyroom in their station as inadequate for working and living in for the long time periods required.	Same as Section A-3.1.	No change.
3. Heater and air circulation systems		
3.1. Heating and ventilation in the gunner's station were rated as inadequate.	The crew compartment shall be provided with a heating system capable of maintaining temperatures above 20 degrees C (68 degrees F) when personnel are not wearing Arctic clothing and exposure is for extended duration (i.e., more than 3 hours) (S 5.12.6.1). The heaters should be capable of maintaining a reference temperature of not less than 5 degrees C at the minimum ambient design temperature with vehicle moving at two-thirds maximum speed and the defrosters operating at maximum capacity (H 3.4.2). Outside fresh air shall be supplied at a minimum rate of 0.57 m3 (20 ft3)/ min./person (S 5.12.6.2). Each crew position within the vehicle compartment must be ventilated properly. Crew ventilation must be separate from engine ventilation and should function properly when the vehicle is stationary or in motion (H 7.5.10.1.2.1).	No change.

Table 1 (continued)

MLRS OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
4. Fire control panel (FCP)		
4.1. The FCP is not equipped with panel lights for illuminating the display at night. The labels, scales and mode settings cannot be read by the gunner when operating the FCP during fire missions at night.	Adjustable illumination shall be provided for visual displays, including display, control and panel labels and critical markings, that must be read at night or under darkened conditions (S 5.1.1.5). (Also S 5.2.1.2.2) The full range of operational conditions should be taken into account in designing display illumination. A display which must be operable under conditions varying from night blackout conditions to full daylight should incorporate the necessary illumination features to allow proper use under all these widely varying conditions (H 1.2.1.1 and H 1.3.6.1.7).	No change.
5. FCP mount		
5.1. The FCP is mounted on a rigid base that transfers vibration from the carrier and shakes the FCP. This makes it difficult to operate while the vehicle is moving.	Where both whole and part body vibrations are not a factor, equipment should be designed so that oscillations will not impair human performance with respect to control manipulations or the readability of numerals or letters (H 3.12.3 and S 5.8.4.2).	No change.
Section C. Driver's Station		
1. Driver's seat		
1.1. The driver's seat was rated as	Same as Section A-1.1.	Seats should include a

Table 1 (continued)

MLRS OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
uncomfortable and lacking adequate support for the long periods of occupation required.		comfortable seat pan and an adjustable back rest. The seat should adjust to provide optimum interface with controls, displays and optical equipment
2. Workspace		
2.1. Workspace for working and living in for long time periods was rated as inadequate.	Same as Section A-3.1.	No change.
3. Suspension lockout pump handle		
3.1. The pump handle is located in a poor position that makes it difficult for either the driver or gunner to operate.	Controls should be designed and located so that the full range of Army personnel can operate them without having to assume awkward positions (H 7.6.1). Handles shall be designed to enhance effective vehicle operation by suitably clothed and equipped users with relevant body dimensions varying between the 5th and 95th percentiles (S 5.12.1).	No change.
4. Controls for instrument panel lights		
4.1. Some of the panel lights cannot be turned off because they are not equipped with control switches. They degrade the driver's vision when he is operating with night vision devices.	Brightness of illuminated markings shall be compatible with the ambient environment and operating conditions (e.g., dark adaptation requirements). Brightness control (dimming) by the operator shall be provided where applicable to maintain appropriate visibility and operator dark adaptation level (S 5.2.2.4.4).	No change.

Table 1 (continued)

MLRS OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
	The full range of operational conditions should be taken into account in designing display illumination. A display which must be operable under conditions varying from night blackout conditions to full daylight should incorporate the necessary illumination features to allow proper use under all these widely varying conditions (H 1.2.1.1). The lighting shall be continuously variable to the full off position (change N2, Mar 82)	
5. Driver's window		
5.1. The top of the driver's window is too low for many drivers; they must bend their backs to see out of the window when driving.	Trucks should be designed to enable the operator, in the normal operating position, to have upward visibility to at least 260 mrad (15 degrees) above the horizontal (S 5.-12.5.3 and H 7.4.20.2).	All driver stations should be designed to enable the operator, in the normal operating position, to have upward visibility to at least 260 mrad (15 degrees) above the horizontal.
6. Driver's windshield wiper		
6.1. The windshield wiper is not located in the correct position. It does not sweep all of the right side which is a critical area for viewing when driving in rainy conditions.	Windshield wipers should clean the areas of the windshield that the driver must see through in order to operate the vehicle properly (H 7.4.21.1).	No change.
7. Blackout lights		
7.1. The blackout lights do not illuminate the forward field of view adequately for safe driving at night.	On a level road, the blackout beam should be 9 meters wide at a point 6 meters in front of the vehicle (de-	No change.

Table 1 (continued)

MLRS OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
	rected at least one degree below the horizontal (H 7.4.18.3.3).	
8. Louver adjustment control		
8.1. The control that opens and closes the driver's louver is unreliable. Sometimes it will fail during travel and the louver will slam shut blocking the driver's view.	Controls shall be designed so as not to be adversely affected by distortion, shock or vibration of the vehicle (S 5.12.3.1).	No change.
9. Fire extinguishier		
9.1. The fire extinguisher is located directly under a heater vent which discharges heated air directly onto it and may cause it to explode.	Risk of explosion should be minimized by isolating hazardous substances from heat sources (H 6.3.5.2).	No change.
10. Driver's stowage compartment		
10.1. Access to the stowage compartment is blocked by the driver's seatback which is permanently attached and not a fold down design.	Structural members of units or chassis shall not prevent access to or removal of items. Replaceable items shall not be mounted in a manner that will make them difficult to remove (S 5.9.4.1). Obstructions (i.e., on structural members) should never block covers so they cannot be opened or removed, or restrict the required access through the cover opening (H 5.2.5.3.h).	No change.

Table 1 (continued)

MLRS OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
11. Air filter panel		
11.1. The screw down latches on the air filter panel located behind the driver's seat are difficult to fasten and release.	Panels that must be removed for maintenance should be held with a minimum of combination-head, captive fasteners. Spring-loaded, quarter-turn fasteners are pArcticularly recommended (H 5.10.3.d.1).	No change.
Section D. Intercom system		
1. Electromagnetic Shielding		
1.1. The intercom picks up noise from transmissions over the digital net which interfers with intercom communications. Crewmen are unable to communicate over the intercom when digital messages are being received.	Design shall reflect allocation of functions to equipment to achieve required reliability of system performance (S 4.3.b). The intelligibility criteria shown in Table VI shall be used for voice communication. The efficiency of communications needed and the type material to be transmitted shall determine which of the requirements of Table VI is to be selected (S 5.3.12.2). It is desirable to maintain as high a speech-to-noise ratio as possible in each frequency band, with pArcticular emphasis on those bands which contribute most to intelligibility (H B.1.-1.5.3.1).	Intercom systems should be installed in vehicles so they are adequately shielded from all sources of acoustic and electromagnetic noise produced by the vehicle.
1.2. Electrical noise produced by the fan is also picked up by the intercom and blocks communications. It must be turned off to communicate over the intercom.	Same as above.	Same as above.

Table 1 (continued)

MLRS OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
Section E. Cab Stowage Space		
1. Cab stowage compartments		
1.1. Overall stowage space in the cab is inadequate.	The design of military systems shall reflect human engineering factors that affect human performance including adequate space for personnel and their equipment (S 4.4.d). Unused space should be utilized to the maximum extent possible to provide suitable stowage for items (H 5.2.5.1).	No change.
Section F. Launcher Loader Module (LLM)		
1. Umbilical cable connectors		
1.1. It is very difficult to connect and disconnect the cable connectors. Contributing factors are that the compartments in which they are mounted are too small restricting access; when the connectors get dirty they become more difficult to connect and disconnect.	Access openings provided for adjusting and handling interior items shall be sized to permit the required operations and where possible, provide an adequate view of the item being manipulated (S 5.9.9.4.1). Connectors should be compatible with the environmental extremes to which they will be subjected (H 5.9.1.1.d). Connectors should be selected, designed, and mounted for easy hand connection/disconnect operation where possible (H 5.9.1.2.e). Connectors should be located so that appropriate access is provided to permit easy performance of the connecting/disconnecting function (H 5.9.1.4.c).	No change.

Table 1 (continued)

MLRS OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
2. Hold down latch handles		
2.1. The handles are difficult and dangerous to operate because they are under great pressure when in the latched position. When unlatching a handle it must be held firmly or it will swing out quickly with great force and strike the operator in the head or upper body causing injury.	The resistance incorporated in levers shall be within the limits indicated in Table 1-7 (measured as linear force applied to a point on the handle) (H 1.1.8.4 and S 5.4.3.2.1.6).	Lever handles that are latched down under high pressures should be equipped with safety devices to prevent them from lashing out at high velocity when released.
3. Boom controller		
3.1. The boom controller is not equipped with panel and indicator lights for night operations. Operators must use a flash light to illuminate the control panel.	Same as Section B-4.1.	No change.
4. Stowage containers		
4.1. The latches on the stowage containers mounted on the underside of the LLM tend to get damaged and broken from normal field service.	The number of fasteners used shall be minimized commensurate with stress and safety requirements (S 5.9.10.1). The following provision has been added to Notice 1 to MIL-STD-1472C, 1 Sep 83: "4.9 Ruggedness. Systems and equipment shall be sufficiently rugged to withstand handling in the field during operation, maintenance, supply and transport within the environmental limits specified for those conditions in the applicable hardware or system specification."	No change.
4.2. The center container is poorly designed. The container door is attached to the bottom of the compartment; stowed contents fall out whenever the door is jarred open.		

Table 1 (continued)

MLRS OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
Section G. Engine, Cab and Hull		
1. Battery box		
1.1. The hexogonal latching nuts on the hold down brackets require too much time to remove for routine PMCS tasks.	Battery holders should be rugged and have easily operated (without tools) clamping devices, to firmly hold the battery in position against all vibration, vehicle motions and gunfire shocks (H 7.4.1.1.1). Hand-operated fasteners shall be given preference (S 5.9.10.1).	No change.
2. Engine access door		
2.1. Access to the engine access door is completely obstructed by the gunner's seat.	Where accessibility depends upon removal of panels, cases and covers, measures shall be taken to insure that such items are not blocked by structural members or other items (S 5.9.4.1). Accesses should be located for direct access and maximum convenience to perform maintenance (H 5.8.5.b). Hoods and other access panels that which must be opened for daily checks must be accessible and operable by a single 5th percentile operator (H 7.4.10.4).	No change.

Table 1 (continued)

MLRS OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
3. Engine hour meter		
3.1. The meter is located down on engine where in cannot be seen from the driver's station.	Displays shall be located and designed so that they may be read to the degree of accuracy required by personnel in the normal operating or servicing positions (S 5.2.1.4.1). Visual displays should be visually accessible without resorting to the use of ladders, flashlights or other special equipment in order to read the display (S 5.2.1.4.2 and H 1.2.-1.4.2).	No change.
4. Cab raising mechanism		
4.1. There is concern that the elevating screw rod that raises and lowers the cab is not strong enough to bear the weight of the cab; crewmen fear it may fail when personnel are working underneath the raised cab.	Units shall be so located and mounted that access to them can be achieved without danger to personnel from moving parts or other hazards (S 5.13.5.2). Are struts and latches provided to keep hinged components from shifting, and thus possibly injuring personnel or equipment (H 6.4.z)?	No change.
5. Hull drain plugs		
5.1. The plugs are too small and do not provide rapid drainage of the rear hull area.	Design features to assure rapidity, safety, ease and economy of operation and maintenance in normal, adverse and emergency maintenance environments (S 4.4.m).	No change.

Table 1 (continued)

MLRS OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
5.2. The plugs are not located at the lowest points of the drainage area where they must be to drain out all the water.	Removal of drain plugs should result in complete drainage of the fluid from each sump or enclosure (H 7.4.-9.2). Prevent drainage problems by providing special drains at low points where necessary (H 5.16.2.4.d).	No change.

Table 2

Comparisons of Significant HFE Design Problems in the M985 Heavy Expanded Mobility Tactical Truck (HEMTT) during MLRS OT III with Current and Proposed Design Criteria

MLRS OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
Section A. Driver's Crew Station		
1. Driver's seat		
1.1. The seat is uncomfortable and does not protect the driver from vibration and jolting from the tightly sprung suspension system.	Seating for vehicle opeators should follow the dimensions recommended in Figures 7-3 and 7-4, and Table 7-1 (H 7.4.17.1). The seat pan should be kept to a minimum, but the seat padding should be resilient enough to keep the operator's body from contacting the seat bottom when experiencing maximum vertical accelerations (H 7.4.17.1.a). Vibration can be reduced and controlled by providing damping materials or cushioned seats (H 3.12.4.c). Where comfort is to be maintained, the acceleration values shown on Figure 42 should be divided by 3.15 (S 5.8.4.1.-1.3 and H 3.12.2.4).	No change.
2. Workspace		
2.1. Workspace was rated as inadequate.	Workspace design and sizing shall insure accomodation, compatibility, operability and maintainability by at least 90 percent of the user population (S 5.6.1). Anthropometric data for the design and sizing of workspace are presented in Table XIX (S 5.7.4).	No change.

Table 2 (continued)

MLRS OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
	Workspace dimensions should follow the data presented in Table 2-15 (H 2.12).	
3. Cab lighting		
3.1. The dome light is not equipped with a red light or filter necessary for night operations.	Where maximum dark adaptation is required and detection by enemy image intensifier night vision devices is not a serious threat, red lighting should be used (H 3.5.3.4).	No change.
3.2. Lighting for map reading was rated as unsatisfactory by crewmen.	To provide a basis for designing the interior lighting system of a vehicle fighting compartment, the tasks of each crew member should be carefully appraised to determine how much illumination they require. Among the duties of the crew, map reading undoubtedly requires the highest level of illumination (H 3.5.31). Illumination of a higher order may be required for difficult tasks within the compartment. Where this requirement exists, auxillery lighting should be provided for such difficult tasks as map reading and instrument panel reading (H 3.5.3.2).	No change.
3.3. The transfer case indicator light cannot be turned off and interferes with use of the night vision goggles.	Brightness control (dimming) by the operator shall be provided where applicable to maintain appropriate visibility and operator dark adaptation level (S 5.2.2.4.4). The full range of operational conditions should be taken into account	Same as Table 1, Section C-4.1.

Table 2 (continued)

MLRS OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
	in designing display illumination. A display which must be operable under conditions varying from night blackout to full daylight should incorporate the necessary illumination features to allow proper use under all these widely varying conditions (H 1.2.1.1).	
4. Vision obstructions		
4.1. Visibility of the right side field of view from the driver's seat was rated as unsatisfactory.	The operator shall have forward visibility through a lateral visual field of at least 180 degrees and preferably 220 degrees (S 5.12.5.2 and H 7.4.-20.1).	No change.
4.2. The side view mirrors were rated as unsatisfactory partly due to excessive vibration.	Mirrors should be braced and clamped so that vibration will not blur the view (H 7.4.19). Vibration of visual displays shall not degrade user performance below the level required for mission accomplishment (S 5.2.1.4.5).	No change.
5. Watertight seals		
5.1. The seals around the doors leak during rainy weather. Water collects on the floor because there is no drainage system in the cab.	Prevent drainage problems by providing special drains at low points where necessary (H 5.16.2.4.d). As with dust, mud and water may be impractical to eliminate as problems affecting comfort, but vehicle design should minimize the problem (H 3.-11.1).	No change.

Table 2 (continued)

MLRS OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
6. Suspension system		
6.1. Crewmen complained that the stiff suspension system gives a hard ride especially when driving an unloaded vehicle over unimproved dirt roads. The vibration and jolting is intense fatiguing the crews and damaging on-board equipment such as the heater fan.	Land vehicles should be designed to control the transmission of whole body vibration to levels that will permit safe operation and maintenance as shown in Figure 42 (see ISO 2631) (S 5.8.4.1.1 and H 3.12.2.1). Where proficiency is required for operational tasks, whole body vibration should not exceed the acceleration values shown on Figure 42 for the time and frequencies indicated (S 5.8.4.1.-1.2 and H 3.12.2.3). Where comfort is to be maintained, the acceleration values shown on Figure 42 should be divided by 3.15 (S 5.8.-4.1.1.3 and H 3.12.2.4).	No change.
7. Blackout lights		
7.1. The blackout lights do not provide adequate illumination of the road necessary for safe driving.	On a level road, the blackout beam should be 9 meters wide at a point 6 meters in front of the vehicle (decreasing in intensity from 6 meters to a point 30.5 meters in front of the vehicle) with the top of the beam directed at least one degree below the horizontal (H 7.4.18.3.3).	No change.
8. M16 rifle racks		
8.1. It is difficult to remove and replace the M16 in the rifle clamps installed in the cab. This causes much annoyance because the rifle rack is a high use item.	Access should be provided (on both sides of equipment if feasible) with sufficient hand room for removal or replacement of equipment (H 7.6.4.-3.c).	Rifle racks in crew stations should be mounted in locations that provide free, unrestricted access for eacy removal/replacement of the weapons. Rifle racks are high use items that must be

Table 2 (continued)

MLRS OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
	The dimensions of access openings for arms, hands and fingers shall be no less than those shown in Figure 45 (S 5.9.9.4.1).	mounted in such a way as to facilitate quick and easy weapon removal/replacement
9. Door latches		
9.1. The door latches tend to stick shut and are difficult to open.	The operator should be able to latch and lock the door easily, in one continuous motion with one hand, from within the vehicle (H 7.5.1.1.3).	No change.
Section B. Cargo Bay and Rear End		
1. Outriggers		
1.1. The task of manually deploying the outriggers was rated as very difficult mainly because it involves heavy push-pull forces and working with equipment fouled with dirt.	Manual horizontal push and pull forces required, to be applied initially to an object to set it in motion or to be sustained over a short period of time, shall not exceed the values of Table XXV (S 5.9.11.4.1 and H 2.4.2.1). Design shall reflect allocation of functions to personnel, equipment and personnel-equipment combinations to achieve required time, safety and reliability of system performance (S 4.3.a and b).	No change.
2. Crane remote control box		
2.1. The feedback dynamics of the controls are very poor; they overcontrol, undercontrol and there are long periods of control lag at times.	Control-display movement ratios for continuous adjustment controller tasks should be selected so as to minimize the total time required for the operator to make the desired control movement, i.e., to accomodate both re-	No change.

Table 2 (continued)

MLRS OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
	sponse time and precision-setting requirements (H 1.3.8.1) and S 5.1.4.1). The time lag between the response of a system to a control input and the display presentation of the response shall be minimized, consistent with safe and efficient system operation (S 5.1.3.2).	
3. Crane main controls		
3.1. The location of the main controls at the rear of the truck is unsatisfactory. The operator does not have a good view of the truck bed and loading area from the rear location.	The crane operator's station should be located where the operator will have the best view of the load, the ground, and other equipment in the vicinity (H 5.15.3.3.a). The placement of controls shall afford optimum visibility of the load at all times (S 5.12.8.3).	No change.
4. Tiedown rings		
4.1. The rings are too small. They cannot accomodate three straps and snap on clips which are required in the tie down method.	Munitions tie-down facilities on stores trailers shall be designed to be easily installed and removed (S 5.12.7.1.3). The design of military systems shall include design features to assure rapidity, safety, ease and economy of operation (S 4.3.m).	No change.
5. Side panel pins		
5.1. The pins are difficult to work with especially when wearing gloves and are easily lost or misplaced because they are unattached.	Pins and other retaining devices should have the maximum working clearances that still assure they will be retained properly. Chains should be	No change.

Table 2 (continued)

MLRS OT III HFE DESIGN PROBLEM	CURRENT HFE DESIGN CRITERIA	PROPOSED CHANGE TO CRITERIA
	used with retaining pins and other similar devices to prevent loss of these items (H 7.4.14.2).	
6. Cargo bay lighting		
6.1. The truck is not equipped with a lighting system for illuminating the cargo bay and loading area which is necessary for performing loading operations at night safely and effectively.	The following factors should be considered when designing illumination systems: the level of illumination required for the most difficult tasks; time and accuracy required in task performance (H 3.5.1.c and e).	No change.
7. Back up lights		
7.1. The backup lights are located too close to the trailer hitch. If the truck and trailer hitches are not aligned during hitching, which occurs frequently at night, the backup lights will smash into the trailer hitch when the vehicles come together.	The Army program for material rediness emphasizes the complementary attributes of reliability and maintainability. Reliability is best expressed as the probability the material will perform its intended function, i.e., remain ready without requiring unplanned maintenance (H 5.1.1). Design shall be such that opreator task accuracy and time constraint do not exceed operator capabilities (S 4.1).	No change.
8. Stowage facilities		
8.1. Stowage space for basic issue items and TA-50 equipment was rated as inadequate.	The design of military systems shall reflect human engineering factors that affect human performance including adequate space for personnel and their equipment (S 4.4.d). Unused space should be utilized to the maximum extent possible to provide suitable stowage for items (H 5.2.5.-1).	No change.

The HFE problems listed in Table 1 were distributed across 36 different design features or equipment components. Current criteria are available for all of them. The criteria were judged to be adequate for 28 features and inadequate for eight. The result suggests that adequate design guidance is available in current criteria to provide designers the information necessary for avoiding most of these problems in the future SPLL systems.

The eight components for which design criteria were judged as inadequate include seating, rifle racks, console mounts, lighting controls, windshield wipers, intercom systems and levers. All of these items are covered by existing criteria in MIL-STD-1472C and MIL-HDBK-759A, but the criteria are not comprehensive in so far that they do not provide guidance for accommodating the HFE considerations that produced problems in the SPLL. Table 1 presents proposed changes to the criteria that address these problems.

The HFE problems were examined by ordering them according to type of component and making a frequency count. The most frequent problems were those concerned with seating, workspace, stowage and illumination systems. The first three items are closely related in that they are associated with comfort considerations in the operator stations. This area emerged as the primary source of inadequate HFE design in the SPLL. Apparently, the outcome occurred partly because the designers did not take into account the long time periods in which the SPLL crew members must occupy their operator stations when performing the MLRS mission. During operations, the SPLL crew members occupy their crew stations almost continuously during both day and night. When they are not actually executing fire missions they are usually on standby sitting in their stations awaiting an alert order to go into action at a moments notice. They literally eat, sleep and work in their operator stations 24 hours a day. Yet the comfort characteristics of the crew stations are quite austere and appear to be designed to support operations for a normal eight-hour a day duty schedule.

Similarily, the many problems with the illumination systems in the SPLL appear to be due to a failure to consider the operational conditions under which they must be used. The SPLL is required to perform its mission during day and night, but the gunner's fire control panel was not provided with a panel lighting system to enable him to read the panel at night. Likewise, when the driver operates under blackout conditions he uses a night vision device (NVD) as standard equipment to enhance his vision. In order to use the NVD he must turn off all of his panel lights because current generation NVDs are extremely sensitive to bright light sources. Nevertheless, some of the panel lights cannot be turned off because they are not provided with the appropriate controls.

Turning to the results presented in Table 2, they indicated that similar problems were encountered in the HEMTT as were found in the SPLL. The HFE problems in Table 2 were distributed across 17 components. Current criteria are available for all of them. The criteria were judged to be adequate for 14 components and inadequate for three. The results also suggest that adequate design guidance is available in current criteria to provide designers the information necessary for avoiding most of these problems in future HEMTT systems.

The three components for which design criteria were judged as inadequate were rifle racks, lighting controls and lighting systems for cargo loading/unloading operations. The first two items were also problems in the SPLL and proposed changes to the criteria for them were presented earlier in Table 1. The third item is peculiar to the HEMTT and Table 2 presents a proposed criterian change for that problem.

As with the SPLL, the most frequent problems observed in the HEMTT were those concerned with seating, workspace and illumination systems. Seating and workspace were again associated with comfort considerations. This problem area was further aggravated in the HEMTT by problems with the stiff suspension system which transfers high levels of shock and vibration to the crew members under certain operating conditions.

The many problems with the illumination systems in the HEMTT again seem to result from a failure to take into account the operational conditions under which they will be used. The dome light is not equipped with a red light for providing blackout lighting in the cab. Auxiliary lighting is not available for map reading which is a critical task for HEMTT operators. Not all of the panel and indicator lights are provided with controls to turn them off when operating with NVDs. Finally, no lighting system was provided for performing ammunition loading/unloading operations safely and effectively at night which is an essential task of the HEMTT's primary mission.

SUMMARY AND CONCLUSIONS

This report has identified current (previously existing) criteria and developed new and revised criteria critical for the HFE design of future MLRS systems. Two general findings emerged from the analysis of HFE problems identified in the OTEA test report: Multiple Launch Rocket System Operational Test III (MLRS OT III (April 1983).

1. On both the SPLL and HEMTT there are two areas in which overall HFE design was insufficient; these were crew station comfort considerations and illumination systems. Current design criteria covering these areas are fairly extensive. Therefore, lack of design guidance does not appear to be the main contributing factor. It seems more likely that the numerous inadequacies resulted from poorly conceived system design concepts which failed to consider fully the comfort and illumination demands that mission requirements place on these vehicles. In order to develop sufficient HFE design concepts for future systems, it is suggested that greater emphasis be given to conducting thorough ongoing front-end analyses. They should be directed toward determining the critical operational conditions and procedures that must be taken into account when developing the HFE design plan for each subsystem in the vehicle.

2. Most of the proposed changes to criteria were made because the current criteria cite address general conditions and do not identify specific components or are for similar components in different systems. In either case there is some doubt whether they are relevant to the components and design problems under consideration. It is felt that offering more narrowly defined criteria which specify both the component and the problem element will eliminate the ambiguity and provide guidance which is more explicit.

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